AD 008 717

WADC TECHNICAL REPORT 52-207

AD 000 8717

MEASUREMENTS WITH HONEYCOMBS IN THE FULL-SCALE AND IN THE MODEL VERTICAL WIND TUNNEL

WILHELM F. KNACKSTEDT, DR. ING.
AIRCRAFT LABORATORY

AUGUST 1952

Statement A
Approved for Public Release

WRIGHT AIR DEVELOPMENT CENTER

20020611006

AF-WP-(B)-O-30 APR 53 50

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The information furnished herewith is made available for study upon the understanding that the Government's proprietary interests in and relating thereto shall not be impaired. It is desired that the Judge Advocate (WCJ), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, be promptly notified of any apparent conflict between the Government's proprietary interests and those of others.

WADC TECHNICAL REPORT 52-207

MEASUREMENTS WITH HONEYCOMBS IN THE FULL-SCALE AND IN THE MODEL VERTICAL WIND TUNNEL

Wilhelm F. Knackstedt, Dr. Ing.
Aircraft Laboratory

August 1952

CEO No. C-3(12)

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This report was prepared by the Wind Tunnel Branch, Aircraft Laboratory, Aeronautics Division, Wright Air Development Center. The test program was initiated at the request of the Project Section of the Wind Tunnel Branch under the research project identified by Capital Expenditure Order Number C-3(12), Acquisition of and Additions to Laboratory Apparatus and Equipment, and was conducted with the full-scale Vertical Wind Tunnel and with a 1:12 scale model of that tunnel at Wright-Patterson Air Force Base, Ohio. The author of this report acted as project engineer.

ABSTRACT

Measurements in the full-scale Vertical Wind Tunnel and in a 1:12 scale model of this tunnel were made to determine if a dynamic pressure distribution required for the spinning of airplane models could be achieved by a honeycomb of conventional type. Test results indicate that a minor change of the nozzle contour at the place where the honeycomb is installed is a possible means to obtain the required dynamic pressure distribution.

PUBLICATION REVIEW

This report has been reviewed and is approved.

W. O. Lippman

for R. G. RUEGG, Colonel, USAF
Chief, Aircraft Laboratory
Directorate of Laboratories

TABLE OF CONTENTS

INTRODUCTION

The purpose of this report is to present and draw conclusions from results attained by pressure distribution measurements in the test section of the Wright Field 12-Foot Vertical Wind Tunnel, and in the test section of the 1:12 scale model of that tunnel with certain arrangements of honeycombs.

This report will be the first one of a series of reports to suggest improvements in the tunnel by various modifications.

SECTION I

GENERAL CONSIDERATIONS

The Wright Field 12-Foot Vertical Wind Tunnel, WADC, at Wright-Patterson Air Force Base, Ohio is of a type often used for spin tunnels. It has an annular return duct which surrounds the test section structure (Reference 1). In its original design, the 12-Foot Vertical Wind Tunnel had some features which experience has shown need modification.

The collector bell diameter was originally made 25% larger than that of the nozzle lip (in similar cases about 10% is usual). The free tunnel jet took a large amount of the surrounding air into the bell. This additional air had to escape again because the mean air mass traveling around the circuit could not increase. Thus, around the bell mouth, air was sucked in and spilled out successively causing vibrations which were so severe at certain tunnel speeds that the test section structure shook. Therefore, bleed holes were cut into the collector bell so that the excessive air could go out somewhat farther downstream. The vibrations were reduced to an amount which could scarcely be felt without instrumentation.

Although the upper return duct should serve as a diffuser, the large increase in cross section area along a relatively short path acts as an excessively wide diffuser and therefore separation occurs. The entrance into and the exit from this diffuser are right angle bends. These bends have small radii of curvature with respect to the channel height; and therefore, at these corners separation, in addition to that caused by the rapid change in cross section area, occurs.

The six guide vanes at the curved entrance are highly loaded because the ratio of spacing to vane chord is large. Separation occurs at the upper surface of these vanes. This separation pattern could be seen from a survey made by means of wool tufts. The improvement of the upper part of the return duct will be the subject of another investigation.

From the separation at the upper part of the return duct great vorticity and relatively large sized vortex balls must be expected.

To avoid the separation, a major change in the building's structure would be necessary. An alternative was to accept, for the time being, the energy loss due to the separation and to attempt to cut down the size of the vortex balls. The rotational velocity of small vortex balls dies out faster than that of large ones. Thus, the flow in the test section would be smoothed. A honeycomb would help the present situation of the tunnel and would also help later on if modifications in the structure were made. The honeycomb was installed in 1947. It had a length to width ratio of the cells of 4:1 and a solidity ratio of 0.02. Investigations by means of pressure distribution measurements around a sphere showed that the turbulence degree of the tunnel had been reduced by the honeycomb from 2.3 to 1.6%.

The possible location of a honeycomb was very limited. Reasonably, it could be installed only in the short distance in front of the nozzle lip, i.e. in the conical part of the nozzle where the structure of the building permitted the installation (Figure 1).

For ease of construction the honeycomb cells were made with parallel walls instead of the preferred converging ones. Therefore, at the rim of the honeycomb, where it touched the converging walls of the nozzle, cells which had the shape of a pyramid and closed pockets which were wedgelike in shape were formed. To open these pockets, the vertical cell walls were cut down to a length such that an exit area was opened which was equal to at least one-half the entrance area of each cell.

Another unfavorable result originated. The flow through the nozzle at the level of the honeycomb has converging streamlines. The difference in inclination between the vertical cell walls and the streamlines is as large as 16° near the walls of the nozzle and tends to approach zero at the centerline of the tunnel. This generally large angle of attack of the straight cell walls with square cut leading and trailing edges causes separation and losses in total pressure which increase toward the rim of the honeycomb. The separation could be observed, by means of a wool tuft probe placed near the cells, by an observer walking around at the bottom of the tunnel.

SECTION II

MEASUREMENTS WITH THE FULL-SCALE TUNNEL

A survey made by pitot-static pressure tubes across the test section of the full-scale tunnel, without the honeycomb installed, is shown in Figure 2; the corresponding survey with the honeycomb in place is shown in Figure 3. The nearly constant dynamic pressure distribution of the empty tunnel has drastically changed.

To give a clearer picture, the dynamic pressure at different points of the test section cross-sectional area was plotted versus the distance of the point from the centerline of the tunnel. The assumption was made that there was rotational symmetry with respect to the tunnel axis.

The dynamic pressure q in percentage of the dynamic pressure q_o in the flow center is constant within a radius $r_i = 4$ feet (Figure 4a) without honeycomb and is still 0.99 q_o at $r_i = 5$ feet. With the honeycomb installed, there is a region of constant dynamic pressure only within a range of $r_i = 1$ foot. At $r_i = 4$ feet, there is left only 0.91 q_o and at $r_i = 5$ feet, 0.83 q_o (Figure 4b).

The high value of q/q_o at $r_i = 5.7$ feet obviously is due to the reduced losses within the cells near the nozzle wall where the cell walls are cut down. Just at the nozzle wall, the dynamic pressure is reduced again because of the boundary layer there.

To prevent a spinning model from wandering out of the jet of a spin tunnel, a bowl-like shape of the dynamic pressure distribution is desirable. This is just the opposite of the distribution produced by the installed honeycomb. To realize the favorable velocity distribution in the test section, it was necessary to cut down the dynamic pressure in the center to an amount less than the reduced dynamic pressure near the edge of the flow (Figure 4c).

This was done by installing a mesh screen 12-feet in diameter beneath the honeycomb. A gap was left between the screen and the nozzle wall. The measured dynamic pressure distribution along a radius of the test section is plotted in Figure 4d.

Of course, these measures caused a large reduction in efficiency. The energy ratio, i.e., the ratio of the fan power put into the tunnel to the power of the jet in the test section is very large. Necessarily, a spin tunnel with safety nets below and above the test section will have a larger energy ratio than a normal tunnel without those accessories. Even so, the energy ratio of this tunnel is 1.6. This value is much too high. If the screen underneath the honeycomb could be eliminated, the energy ratio then would be about 1.2.

SECTION III

MEASUREMENTS WITH THE MODEL TUNNEL

A. Modifications of the Honeycomb

To find a way to correct this unfavorable feature of the full-scale tunnel, tests were performed with the available 1:12 scale model spin tunnel. A geometrically similar model of the honeycomb (Figure 5) was installed at the corresponding location in the nozzle of the model tunnel. A survey along a diameter of the test section by means of a movable total pressure tube was made and the dynamic pressure q in percentage of the dynamic pressure q_o near the tunnel axis was plotted in Figure 6.

The dynamic pressure distribution in the test section with and without honeycomb (Figures 6a and 6b) is of the same type as that in the full-scale tunnel except in regions where the flow is not separated at sharp edges and therefore the Reynolds number has an influence. The higher losses in the model tunnel near the nozzle wall may be caused by the 1/12 smaller Reynolds number, the consequence of which is a higher wall friction coefficient.

The next step in the investigation was to produce a somewhat more favorable dynamic pressure distribution by cutting the model honeycomb to 10 inches in diameter and reinstalling it in its original position. The dynamic pressure distribution was changed drastically (Figure 6c) leaving a higher dynamic pressure near the edge of the flow because of the gap of about 2 1/2 inches between the rim of the honeycomb and the nozzle wall. The distribution near the center of the jet did not change in comparison to that of Figure 6b.

The honeycomb of 10 inches diameter then was installed in a position in the model tunnel just where the cylindrical part of the nozzle starts. Here at least the streamlines in a considerable circular section around the center of the jet were parallel or nearly parallel to the honeycomb cells. A bowl-like shape of the dynamic pressure distribution was produced (Figure 6d). Near the rim of the cut honeycomb the streamlines probably diverged because of the almost undisturbed flow in the gap, causing an angle of incidence for the outer cells and therefore higher losses. In the gap itself the smaller losses provided a higher dynamic pressure again.

From this test it can be seen that the honeycomb with parallel cell walls does not necessarily have to be located in a completely parallel flow, although of course large inclinations between flow and cell walls should be avoided.

B. Modification of the Nozzle Contour

It would be very favorable if a honeycomb could be located far upstream of the test section in some cylindrical part of the nozzle and at a cross section where the velocity is still low.

The structure of the full-scale tunnel building would allow a modification of the nozzle so that there would be a cylindrical part with a relatively large diameter of about 18 feet and a sufficient length to install a honeycomb with parallel cell walls. Of course this would require a major structural change and a lengthy shutdown of the tunnel.

Therefore, it was decided to test first an arrangement in the model tunnel which would require a much smaller change of the full-scale tunnel. This was a ring installed within the nozzle, the cross section profile of which provided a cylindrical part in the nozzle at a place where the honeycomb will be located, Figure 7. The dynamic pressure distribution across the test section is not changed in comparison to the distribution without a ring in the nozzle as shown in Figures 6a and 6e.

To get a picture of the flow through the part of the nozzle where the honeycomb is to be installed, a plate of sheet metal coated with oil and fine sawdust was fitted into the nozzle. The flow then would take small particles with it leaving traces in the oil film.

It was expected that the flow through the nozzle would follow the nozzle wall and therefore be vertical near the wall of the inserted ring. The flow also should be straight and parallel on the flow axis and in the neighborhood thereof. In between, the flow probably should be somewhat conical because of the curvature of the flow through the nozzle in front of the ring and the lack of guidance thereafter. That means that the flow in between should have a certain inclination to the straight parallel honeycomb cell walls which thus should straighten the flow.

The oil flow pattern on the sheet metal insert in Figure 8 looks somewhat different from the air flow pattern described above. This is natural since the traces on the metal surface cannot be considered as the streamlines in the real nozzle flow. There is a boundary layer on the metal surface and the dust particles traveling within the boundary layer follow the flow to regions of low static pressure close to the wall of large curvature. Therefore, the streamlines seem to penetrate the nozzle wall which of course cannot be. That means that all the traces of the dust particles between the wall and the centerline must be bent away from the nozzle wall to become streamlines. Then, it is indicated that the streamlines between the nozzle wall and the axis are still somewhat convergent.

From comparison with honeycombs in other wind tunnels the width to depth ratio of the cells 1:4 for the full-scale honeycomb was considered insufficient and a ratio 1:8 to be more favorable. Because the honeycomb depth is limited, by the height of the cylindrical part of the nozzle insert, to not more than 2 inches, the cell width of the model tunnel honeycomb must be 1/4 inch or less. The fabrication of such a honeycomb would have been laborious. Therefore, samples of a honeycomb material generally used for light structural purposes and made from paper or fiber soaked with artificial resin were cut into suitable lengths and installed as a honeycomb.

Tests with a paper honeycomb and with one made out of glass fiber show a dynamic pressure distribution favorable to spin investigation (Figures 6f and 6g).

The small cells unfortunately are subject to clogging by dust particles within the tunnel, thus changing the pressure distribution. The true distribution was obtained only during the first runs after the dust had been carefully cleaned from the tunnel and the honeycomb. The glass fiber honeycomb became clogged sooner than the paper honeycomb because the leading edges of the cell walls always stayed somewhat fuzzy and collected dust much more easily.

The solidity of the honeycomb, i.e., the projected area of the solid material in percentage of the total area, was not uniformly distributed over the honeycomb area. This changed the dynamic pressure distribution which could be expected from a uniform solidity.

Another honeycomb then was built from paper drinking straws carefully cut into suitable lengths and glued side by side into a solid block. Both sides of the honeycomb were sanded and the leading and trailing edges were carefully smoothed. The solidity obviously was much more evenly distributed and when the tunnel and the honeycomb were cleaned often, a nearly bowl-shaped dynamic pressure distribution resulted (Figure 6h).

The energy ratio in the model tunnel with the nozzle ring and the honeycomb was found to be 1.08 to 1.17 for the paper honeycomb and 0.94 to 0.99 for the glass fiber honeycomb. That for the straw honeycomb could not be compared because in the meantime essential modifications in the model tunnel were made. The difference in the energy ratio between the two honeycombs was caused by the different solidity. Only an average value of the solidity could be determined, 0.17 for the paper, 0.08 for the glass fiber and 0.17 for the straw honeycomb.

The values of the energy ratio are not too consistent because the narrow cells became clogged very easily. At least the necessary energy ratio will be smaller for a honeycomb of larger cell size and the same or even smaller solidity.

This indicates that an arrangement in the full-scale tunnel like that in the model tunnel would give a reduction in energy ratio to at least 1.0 if the dynamic pressure distribution should prove satisfactory with the new honeycomb. Although there are indications that the new honeycomb will prove satisfactory, there is no definite proof because the non-uniform solidity distribution of the model honeycombs does not give the details of the dynamic pressure distribution accurately enough. The solidity of the new full-scale honeycomb will be 0.04 and evenly distributed.

The favorable effect of the twelve times higher Reynolds number in the full-scale tunnel has not yet been taken into account. Both the friction losses at the cell walls due to the higher Reynolds number and due to the smaller solidity, result in a reduced drag coefficient of the new honeycomb. Therefore, a further reduction in energy ratio can be expected.

SECTION IV

SUMMARY

The measurements on honeycombs in the full-scale and the Model Vertical Wind Tunnel show:

1. The present full-scale honeycomb with parallel walls does not fit into the flow pattern of convergent streamlines. Separation losses occur, causing an unsatisfactory dynamic pressure distribution and an energy ratio of about 1.2. A screen which causes a large drag is necessary to provide the required dynamic pressure distribution; however, it increases the energy ratio to 1.6.

2. The new contour of the nozzle gives a cylindrical part of sufficient length that a honeycomb of conventional type with parallel cell walls can be installed.

3. The straightening effect of the new honeycomb is improved by increasing the length to width ratio of the cells from 4:1 to 8:1.

4. In view of the model measurements, a favorable dynamic pressure distribution and an energy ratio of about 1.0 can be expected from the new arrangement in the full-scale tunnel.

REFERENCE

1. Crawford, R. Vertical Wind Tunnel Added to Air Force Test Facilities. Technical Data Digest. Vol. 13, No. 23. United States Air Force, Air Materiel Command, December 1948, pp. 8 - 10. (Unclassified, English).

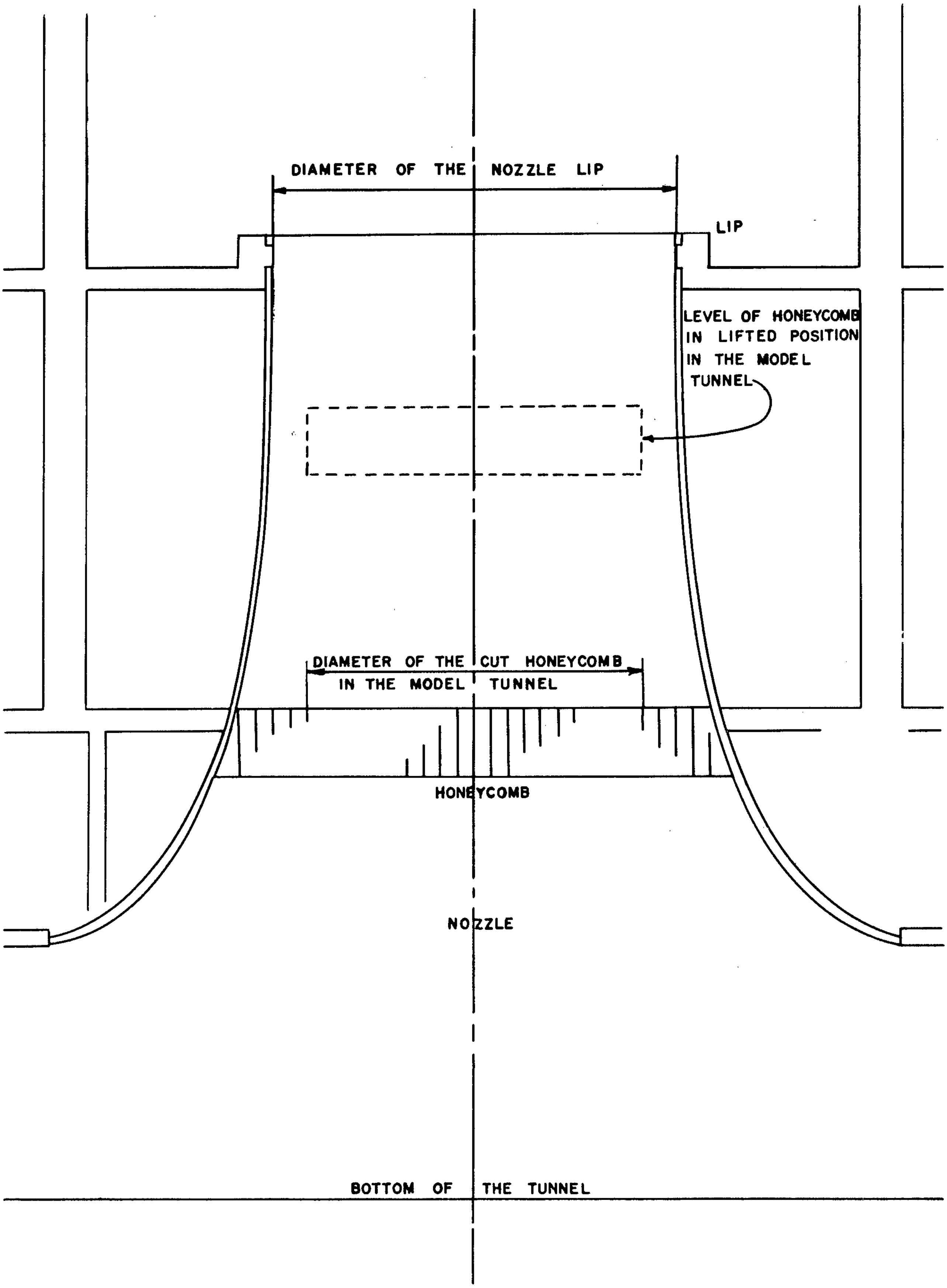


FIGURE 1: GENERAL ARRANGEMENT OF NOZZLE AND HONEYCOMB IN FULL-SCALE AND MODEL TUNNEL.

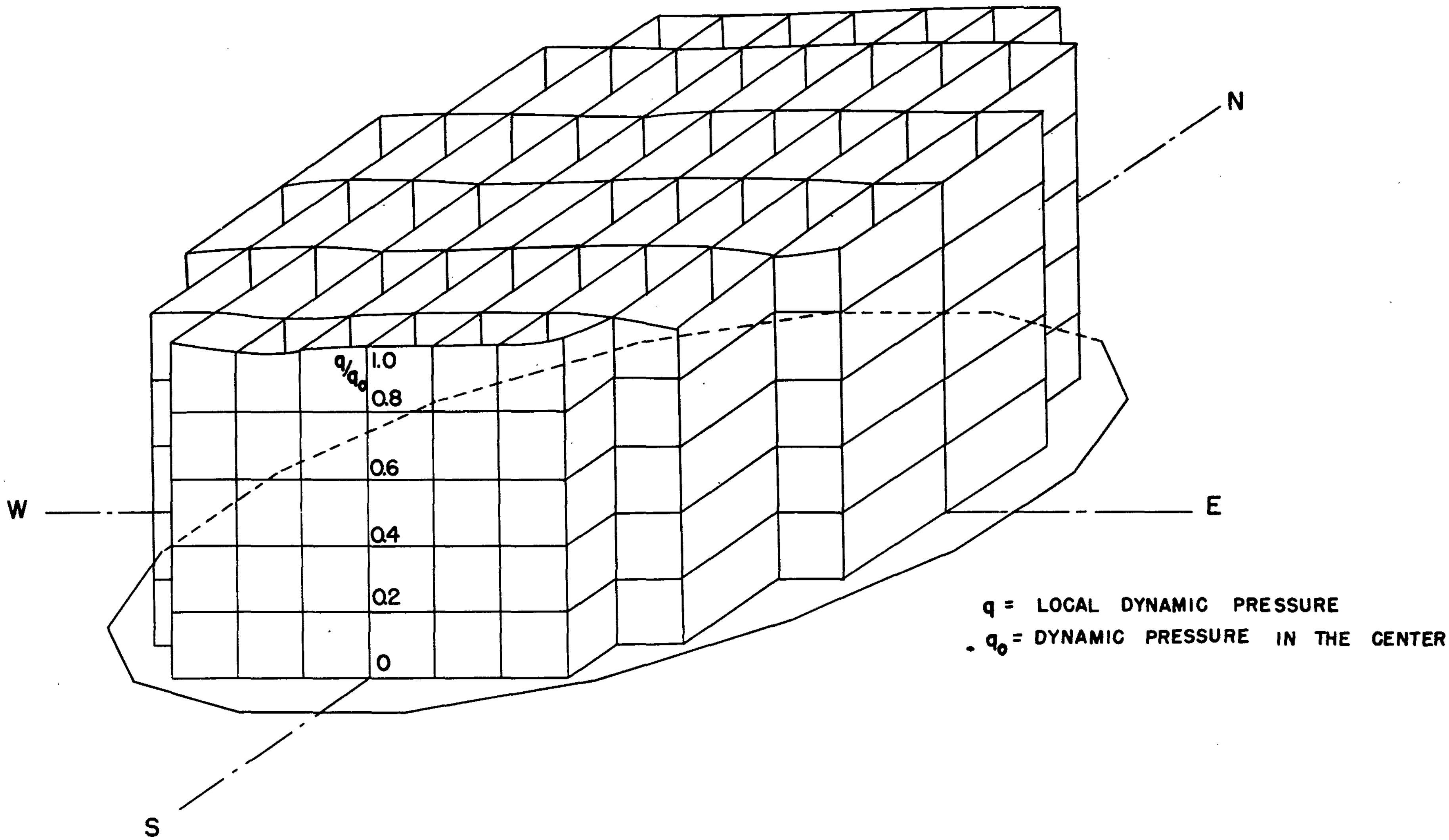


FIGURE 2: DYNAMIC PRESSURE DISTRIBUTION IN THE TEST SECTION OF THE FULL SCALE TUNNEL WITHOUT HONEYCOMB

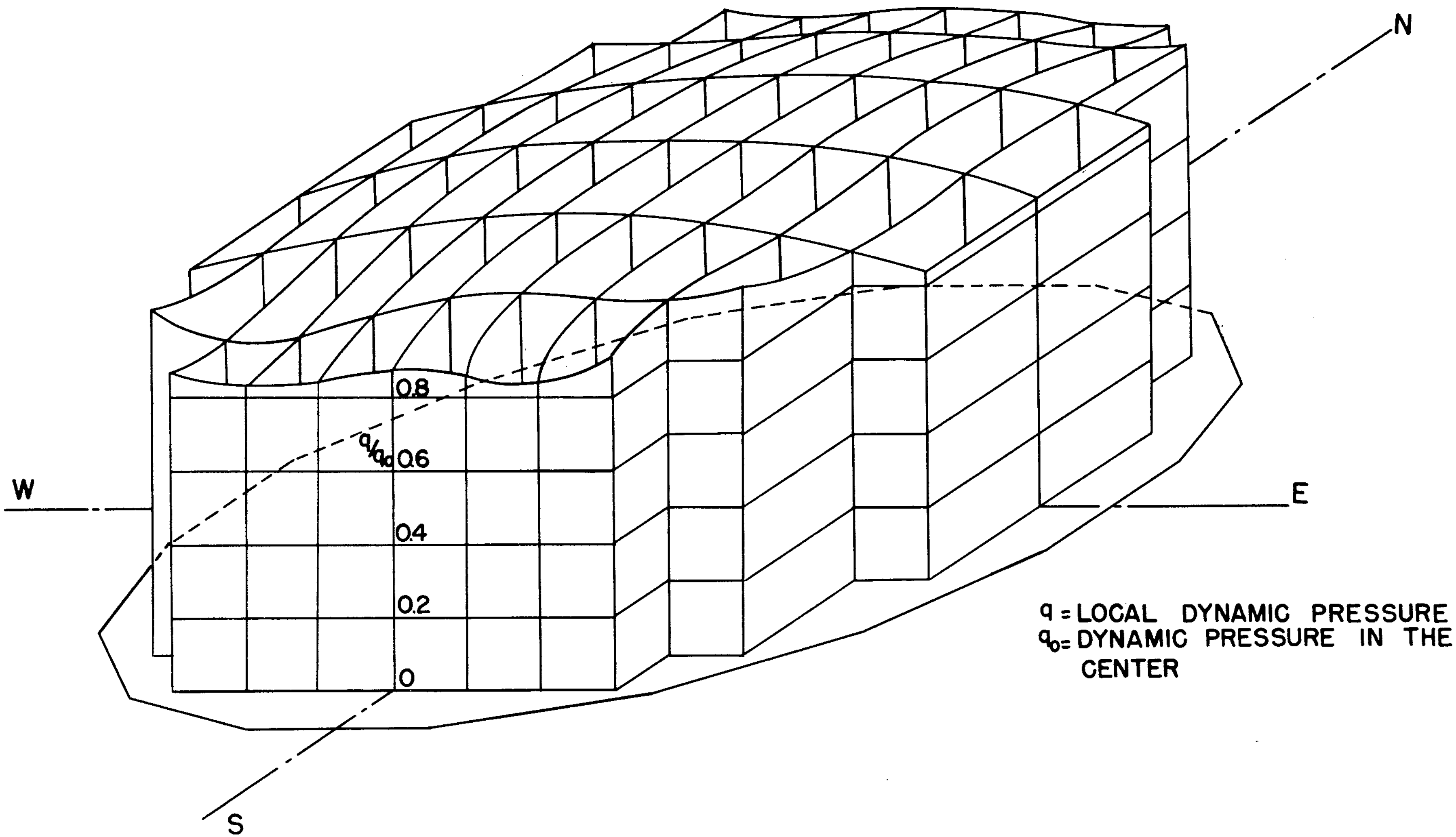


FIGURE 3: DYNAMIC PRESSURE DISTRIBUTION IN THE TEST SECTION OF THE FULL SCALE TUNNEL WITH HONEYCOMB

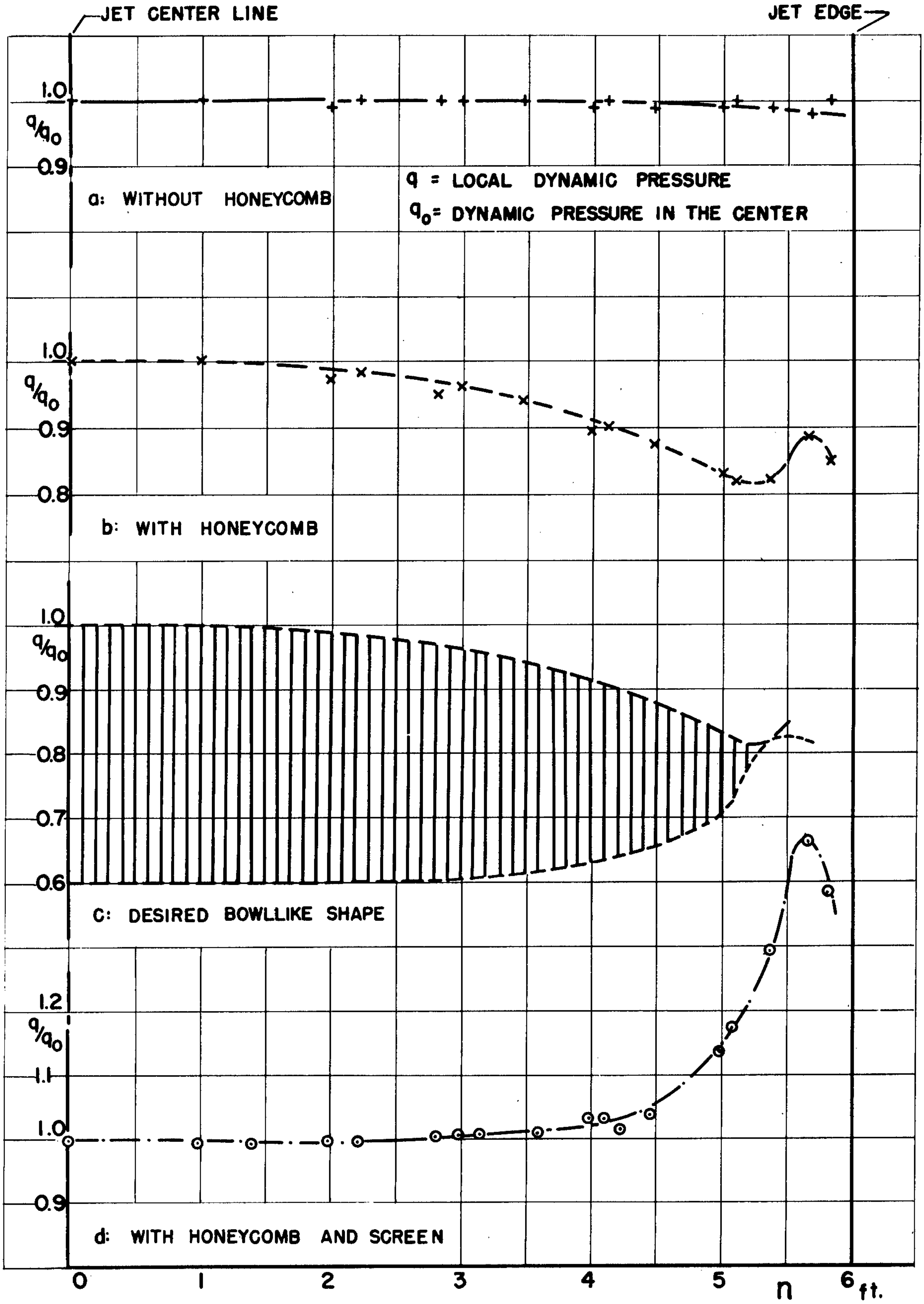


FIGURE 4: DYNAMIC PRESSURE DISTRIBUTION ALONG A RADIUS OF THE TEST SECTION IN THE FULL SCALE TUNNEL

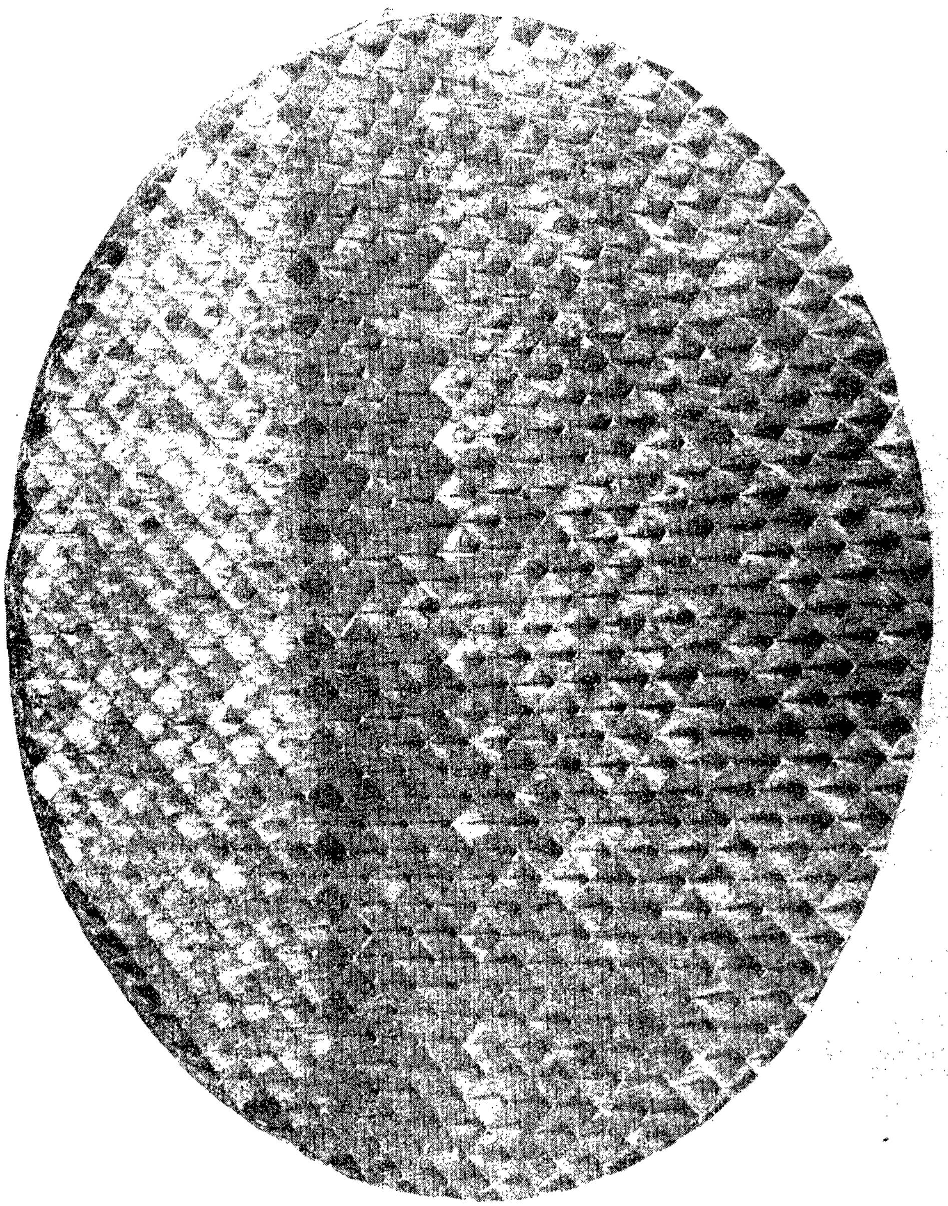
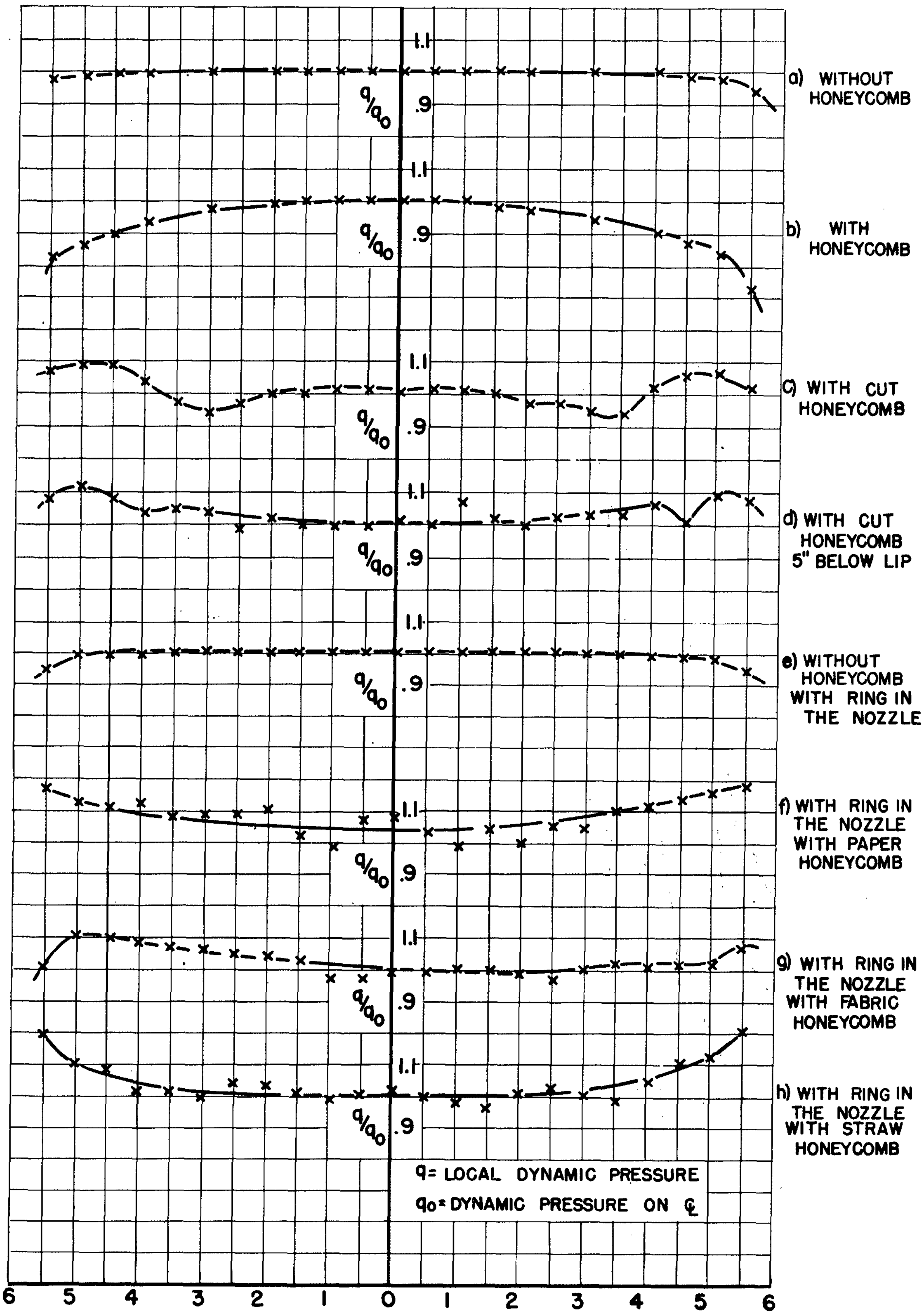


FIGURE 5: HONEYCOMB OF THE MODEL TUNNEL



FIGURES 6a TO 6h: DYNAMIC PRESSURE DISTRIBUTION ALONG A DIAMETER OF THE MODEL TUNNEL TEST SECTION

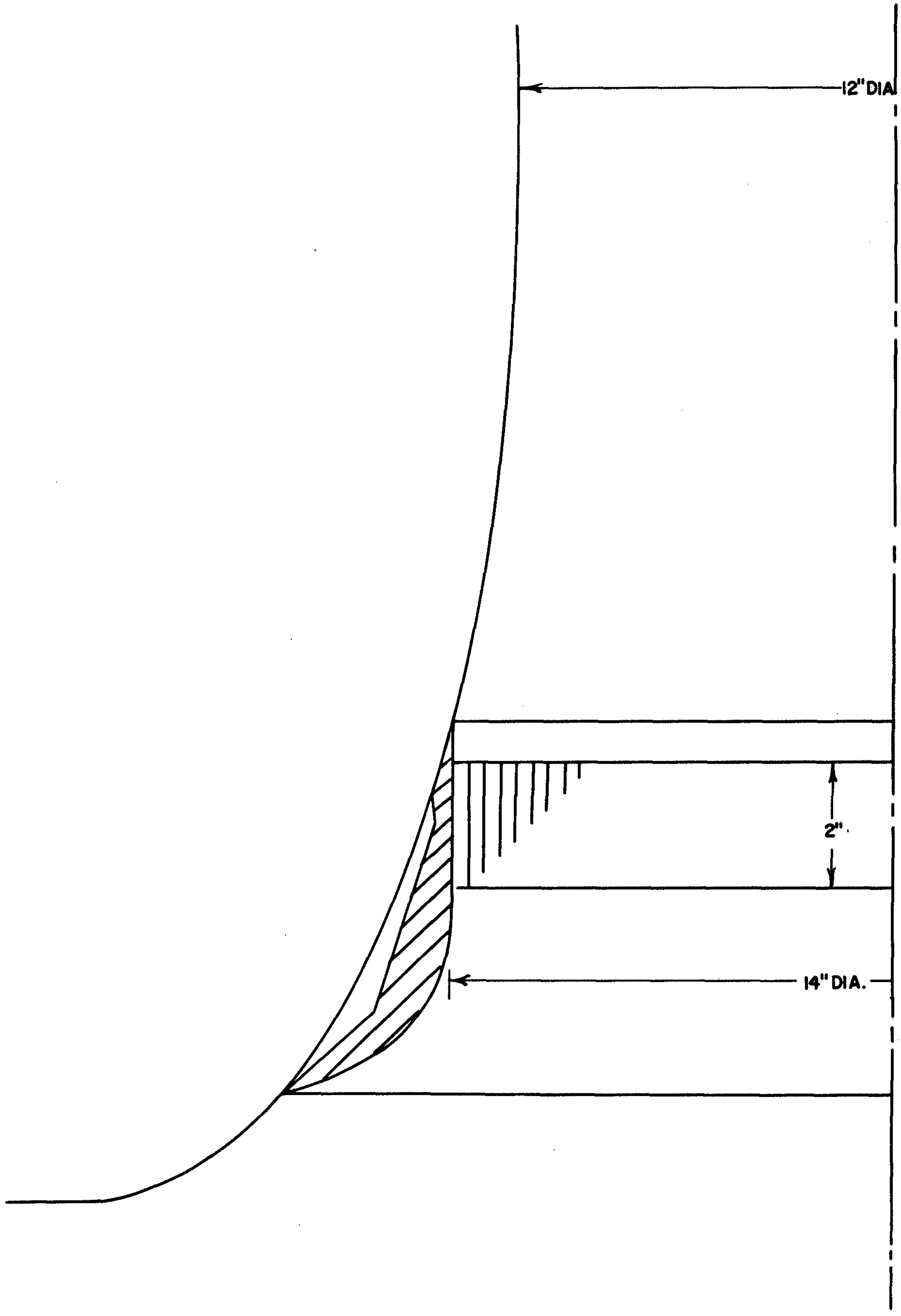


FIGURE 7: NOZZLE RING IN THE NOZZLE OF THE MODEL TUNNEL WITH HONEYCOMB

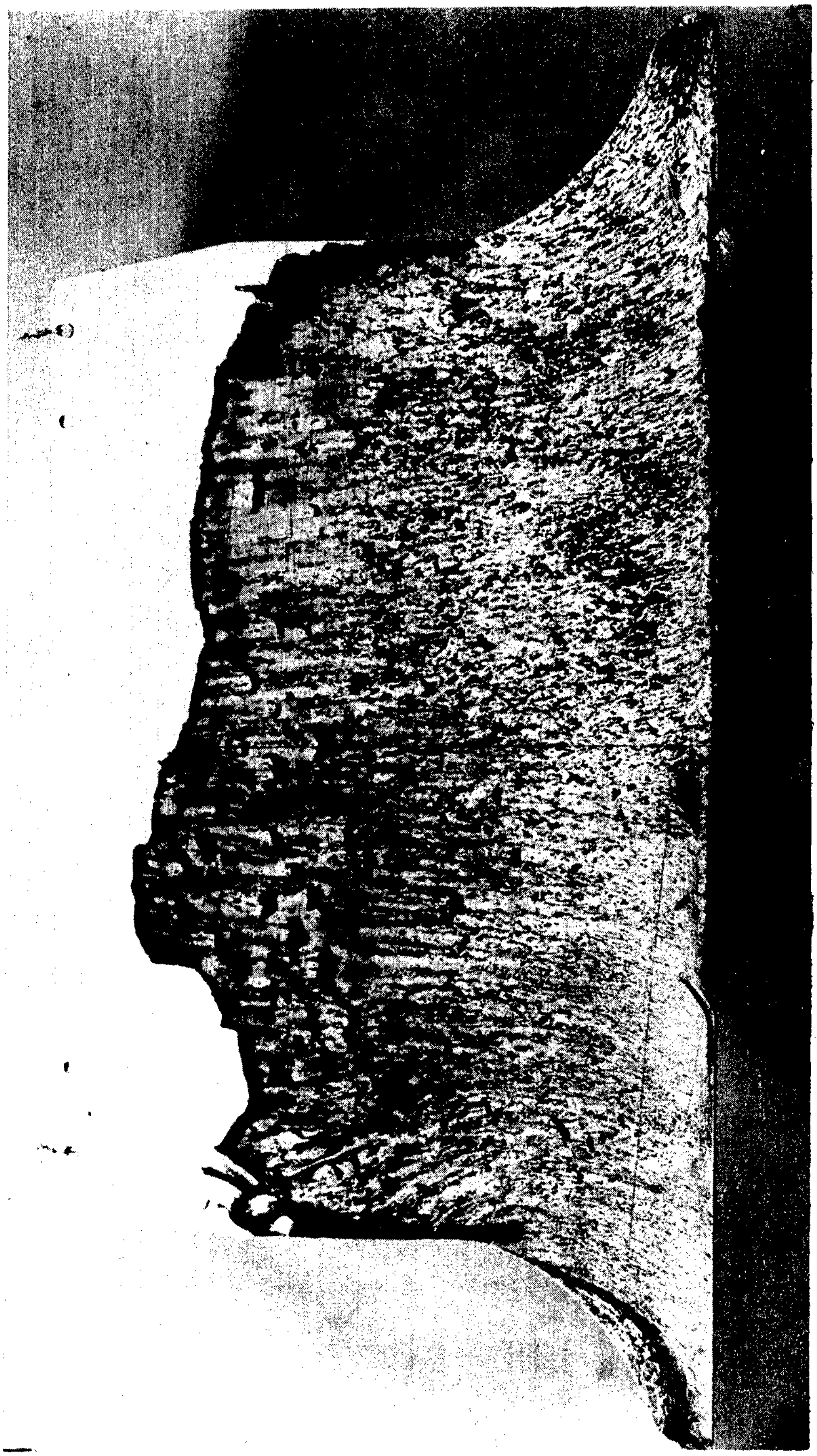


FIGURE 8: PATTERN OF THE FLOW THROUGH THE NOZZLE